The First Semiannual Report of the Project Entitled "Evaluation and Improvement of Spray-Modified Air-Sea Enthalpy and Momentum Flux Parameterizations for Operational Hurricane Prediction"

Prepared for:

Joint Hurricane Testbed
Tropical Prediction Center
11691 SW. 17th Street
Miami, FL 33165

Prepared by:

Jian-Wen Bao, Christopher W. Fairall, Sara A. Michelson

NOAA/Earth System Research Laboratory

325 Broadway, Boulder, CO 80305-3328

(in corporation with Drs. Naomi Surgi and Young Kwong at NOAA/NWS)

Submitted on December 28, 2007

Table of Contents

1. EXECUTIVE SUMMARY

This report summarizes the first 6-month progress of a project sponsored by the Joint Hurricane Testbed, in which a bulk parameterization scheme of air-sea sensible and latent heat fluxes developed at NOAA/ESRL is implemented and tested in the operational HWRF model. The project has progressed well during the first six months as planned in the project proposal. The most recent version of NOAA/ESRL sea-spray scheme has been added to the HWRF model physics suite. Experimental runs of the model with the scheme have been carried out for five historical major hurricane events to examine the sensitivity of the HWRF model to the sea-spray physics. It is found the impact of the sea-spray scheme on the HWRF model is positive. The preliminary results indicate that the scheme improves the HWRF model's intensity prediction with little impact on the track prediction.

2. INTRODUCTION

During the past six months, a bulk parameterization scheme of air-sea sensible and latent heat fluxes developed at NOAA/ESRL was implemented, tested and evaluated in the newly developed hurricane WRF-NMM (HWRF) model. This scheme was developed as an extension of the TOGA-COARE bulk flux model (Fairall et al. 1994), and has been refined with observations from new field campaigns (such as the CBLAST experiment) and updated theoretical understanding (Fairall et al. 2007). The objectives of the project for the first six months were accomplished with great help from Dr. Naomi Surgi's group at NCEP of NOAA/NWS. The NOAA/ESRL team visited NCEP in July 2007 to coordinate with Naomi Surgi's group. Collaborative effort has also been started with Dr. Isaac Ginis' group at the University of Rhode Island to further the physical understanding of the impact of the spray-mediated thermal and momentum fluxes on the marine atmospheric boundary layer dynamics.

3. MODEL SETUP

The HWRF model was set up by Drs. Naomi Surgi and Young Kwong at NCEP in the same way as the operational prediction experiment, in which a two-way nested grid included a moving inner grid which followed the storm center. The NOAA/ESRL sea-spray parameterization was added to the atmospheric boundary layer physics subroutine. After consulting Drs. Naomi Surgi and Young Kwong, five hurricane cases were chosen to test and calibrate the scheme: Katrina (2005), Rita (2005), Emily (2005), Dennis (2005) and Helene (2006). All the HWRF model forecasts presented in this report were run on the IBM supercomputer system at NCEP.

The current version of the NOAA/ESRL sea-spray scheme has two tunable parameters — the droplet source strength, *ss*, and the feedback strength, *ft*. The determination of appropriate values of these two parameters is still *ad hoc* due to the lack of observational information to quantify how sea-spray droplets modify the mean temperature and moisture profiles in the surface layer. Initially, the approach to specifying the two parameters for a given model is to permute (*ft*, *ss*) with various possible values, and to examine the sensitivity of the hurricane simulations to various permutations of (*ft*, *ss*) by comparing the simulation results with the best track information.

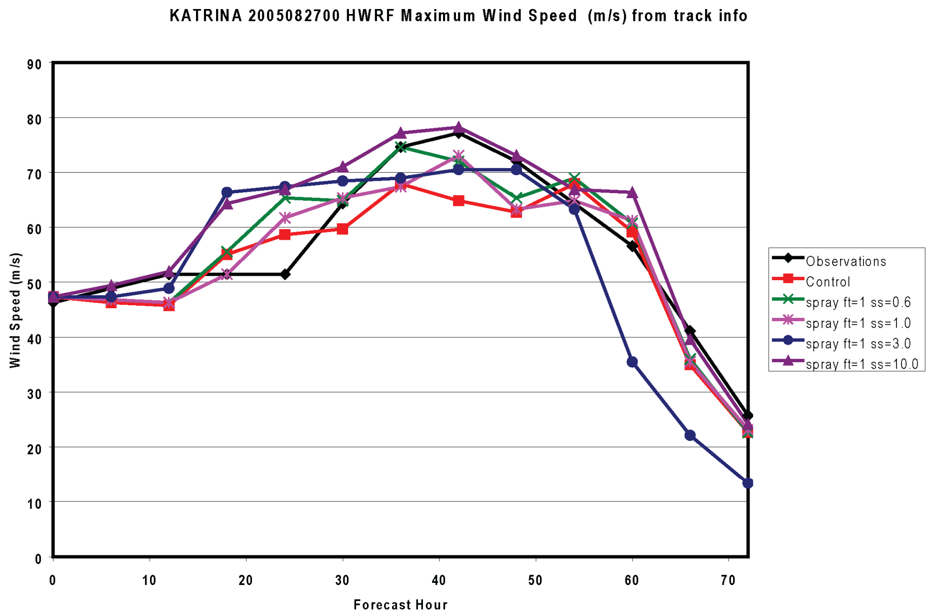
As pointed out in the project proposal, first physical principles will be applied later on to reduce the number of tunable parameters so that the feedback parameterization will become physically sound and robust. As a matter of fact, progress has been made in this regard. Numerical experiments are ongoing with the improved feedback parameterization, and the results will be summarized in the second semiannual report.

4. PRELIMINARY RESULTS

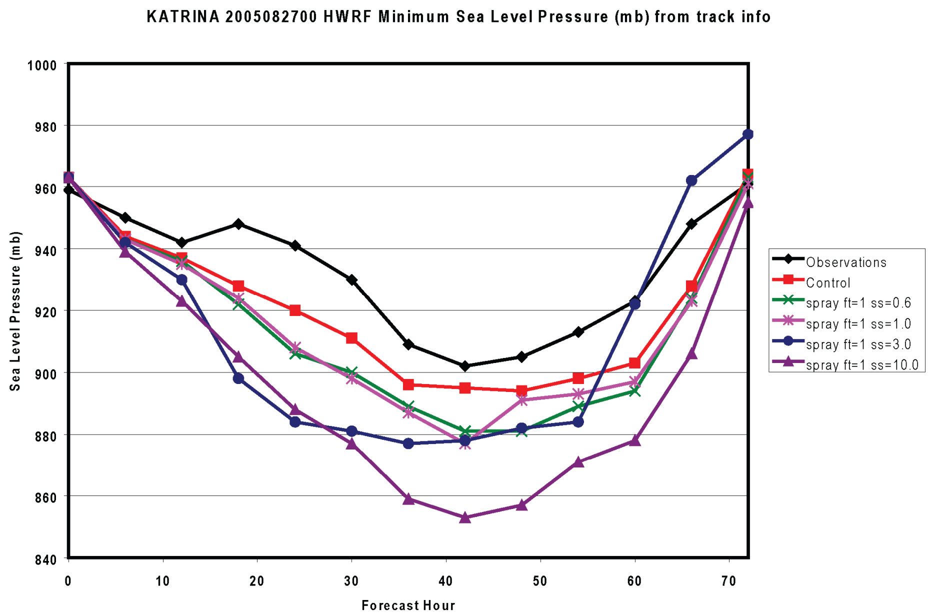
This section summarizes the results from the sensitivity experiments to calibrate the two tunable parameters, *ss* and *ft*, in the NOAA/ESRL sea-spray parameterization scheme. For the purpose of highlighting the major findings so far from this project, only the results from the HWRF runs with *ss* = 0.6, 1, 3 and 10 while *ft* = 1 are discussed by comparison with the control run in which the sea-spray parameterization is turned off.

4.1 Katrina (2005)

Figure 1 shows the maximum surface winds (Fig. 1a) and sea-level pressure (Fig. 1b) for the predictions of Hurricane Katrina (2005) with ss = 0.6, 1, 3 and 10 while *ft* = 1. The model was initialized at 0000 UTC 27 August 2005. It is seen that for a fixed *ft*, there is a general trend that the predicted intensity at the peak of the intensification increases with *ss*. Although the predicted minimum sea-level pressure decreases as the intensity increases, the predicted minimum sea-level pressure is lower than the best track estimate. It is encouraging that while the predicted intensity varies with different values of *ss*, the predicted track does not change significantly (Table 1) in comparison with the control run in which the sea-spray effect is not included. This indicates that the sea-spray modification to the air-sea enthalpy exchange does not affect the track. It should also be pointed out that the differences among various runs are not proportional to differences in the values of *ss*, indicating that the relationship between the intensity at a given time results from a very nonlinear interaction between the storm dynamics and the air-sea thermal fluxes.



(a)



(b)

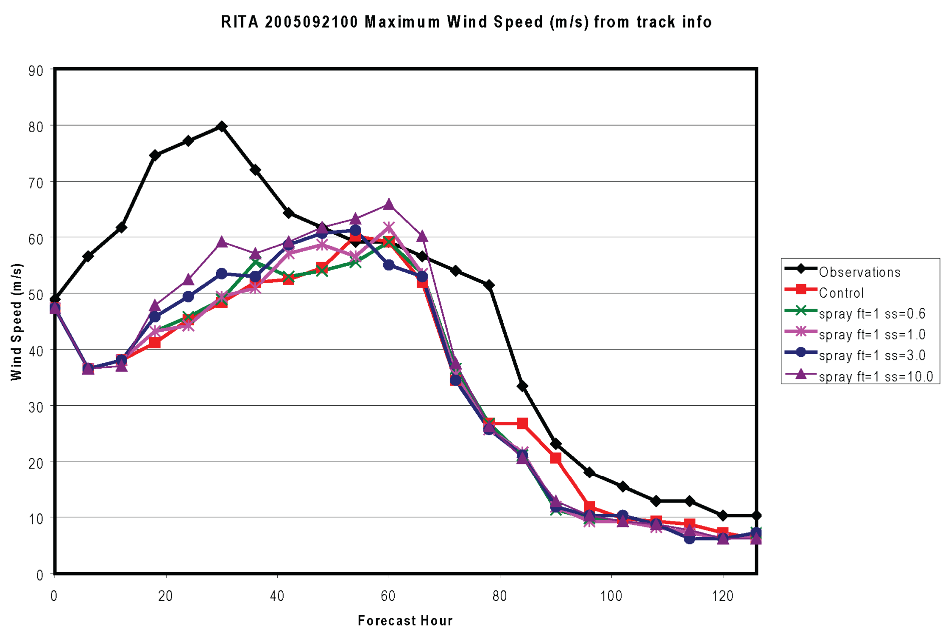
Figure 1: The maximum surface winds (ms^{-1}) (a) and sea-level pressure (mb) (b) for Hurricane Katrina (2005) with *ss* = 0.6, 1, 3 and 10 while ft = 1. The black line (labeled as Observations) is the best track estimate. The red line is the control run without the sea-spray parameterization. The model was initialized at 0000 UTC 27 August 2005.

forecast hour	Control lat	Control lon	*ss*=0.6 lat	*ss*=0.6 lon	*ss*=1 lat	*ss*=1 lon	*ss*=3 lat	*ss*=3 lon	*ss*=10 lat	*ss*=10 lon
0	25.0N	82.9W	25.0N	82.9W	25.0N	82.9W	25.0N	82.9W	25.0N	82.9W
6	25.1N	83.9W	25.1N	83.9W	25.1N	83.9W	25.1N	83.9W	25.1N	83.9W
12	25.1N	84.8W	25.1N	84.8W	25.1N	84.8W	25.1N	848.W	25.1N	84.8W
18	25.2N	85.7W	25.2N	85.7W	25.2N	85.7W	25.2N	85.7W	25.2N	85.7W
24	25.5N	86.5W	25.5N	86.5W	25.5N	86.5W	25.5N	86.5W	25.5N	86.5W
30	25.9N	87.5W	25.9N	87.5W	25.9N	87.5W	25.9N	875W	25.9N	87.5W
36	26.5N	88.4W	26.4N	88.4W	26.5N	88.4W	26.5N	88.5W	26.5N	88.4W
42	27.1N	89.3W	27.1N	89.3W	27.2N	89.4W	27.2N	89.3W	27.1N	89.4W
48	27.8N	89.7W	27.8N	89.8W	27.8N	89.9W	27.9N	89.8W	27.8N	89.8W
54	28.8N	90.0W	28.8N	90.1W	28.8N	90.0W	28.9N	90.0W	28.8N	90.1W
60	29.9N	90.0W	29.9N	90.2W	29.9N	90.1W	30.1N	90.0W	29.8N	90.2W
66	31.1N	90.0W	31.0N	90.0W	31.1N	89.9W	31.2N	89.9W	31.1N	90.1W
72	32.1N	89.3W	32.1N	89.5W	32.1N	89.4W	32.3N	89.2W	32.1N	895.W
78	33.1N	88.6W	33.2N	88.7W	33.1N	88.6W	33.4N	88.4W	33.2N	88.8W
84	34.3N	87.4W	34.3N	87.6W	34.4N	87.4W	34.7N	87.3W	34.5N	87.7W
90	35.8N	86.2W	35.8N	86.3W	35.9N	86.2W	36.2N	86.1W	35.9N	86.4W
96	37.3N	84.9W	37.3N	85.1W	37.3N	84.7W	37.3N	84.6W	37.0N	85.0W
102	38.1N	83.6W	38.0N	83.9W	38.4N	83.3W	38.6N	83.1W	38.2N	83.6W
108	38.9N	81.8W	38.9N	82.1W	39.0N	81.9W	39.1N	81.6W	39.0N	82.0W
114	39.9N	79.3W	30.5N	79.9W	40.1N	79.4W	399N	79.6W	39.5N	80.0W
120	40.6N	77.0W	39.8N	77.5W	40.8N	76.9W	40.6N	76.9W	39.3N	77.2W
126	41.0N	74.9W	40.5N	75.3W	41.5N	74.1W	41.7N	74.5W	40.5N	74.7W

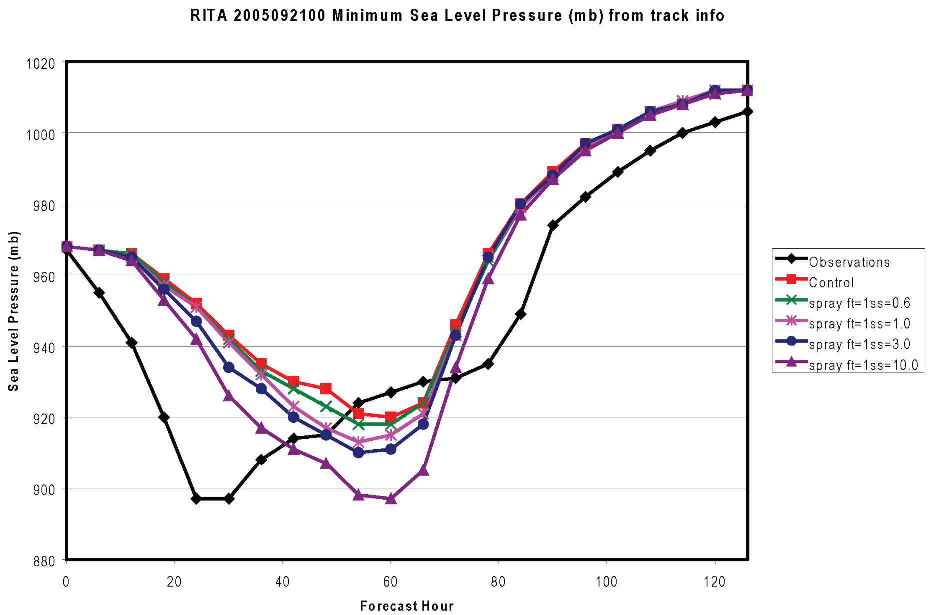
Table 1: Predicted track locations of Hurricane Katrina without the sea-spray parameterization (control) and with the sea-spray parameterization in which *ss* = 0.6, 1, 3 and 10 while ft = 1.

4.2 Rita (2005)

The results from the experiment with Hurricane Rita (2005) are shown in Figure 2 and Table 2. The model was initialized at 0000 UTC 21 September 2005. As in the Katrina case, for a fixed ***ft*****,** the predicted intensity of the hurricane increases with *ss*. Again, while the predicted intensity changes with different values of *ss*, the predicted track does not change significantly (Table 2). Also, the nonlinear variation of the predicted intensity with *ss* is very similar to that shown in the Katrina case. It should be pointed out that, unlike the Katrina case, there is delay in the predicted intensification in all the runs when compared with the best track estimate and the sea-spray effect is not able to make any improvement in the timing bias of intensification. It is interesting to note, that while the run with *ss* = 10 is in fairly good agreement in the strength of Hurricane Rita in terms of sea level pressure, the maximum wind speed at the time of the minimum sea level pressure is too weak by about 15 ms^{-1}.



(a)



(b)

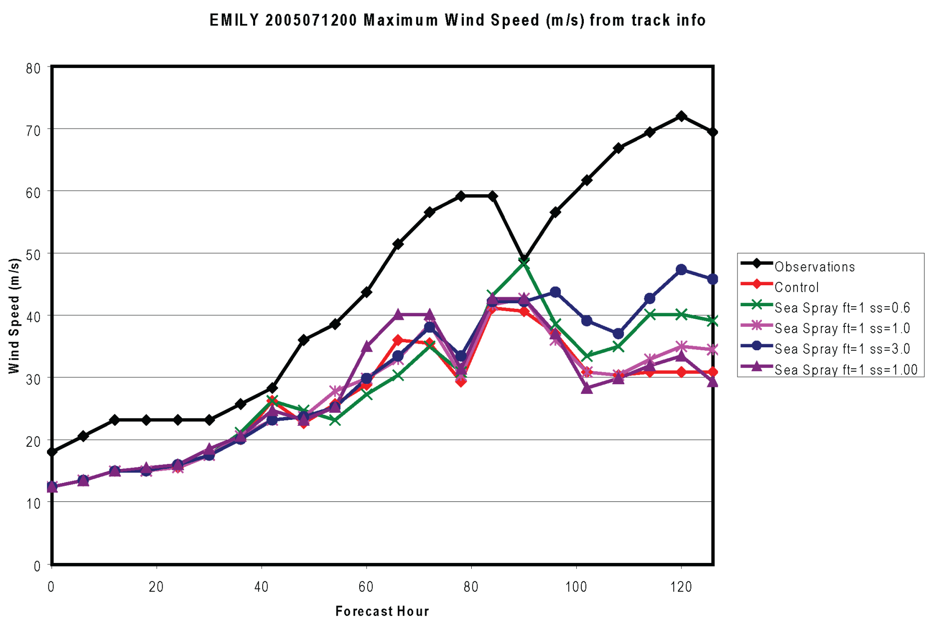
Figure 2: The maximum surface winds (ms^{-1}) (a) and sea-level pressure (mb) (b) for Hurricane Rita (2005) with *ss* = 0.6, 1, 3 and 10 while *ft* = 1. The black line (labeled as Observations) is the best track estimate. The red line is the control run without the sea-spray parameterization. The model was initialized at 0000 UTC 21 September 2005.

forecast hour	Control lat	Control lon	*ss*=0.6 lat	*ss*=0.6 lon	*ss*=1 lat	*ss*=1 lon	*ss*=3 lat	*ss*=3 lon	*ss*=10 lat	*ss*=10 lon
0	24.0N	82.6W	24.0N	82.6W	24.0N	82.6W	24.N	82.6W	24.0N	82.6W
6	24.1N	84.1W	24.1N	84.1W	241N	84.1W	24.1N	84.1W	24.1N	84.1W
12	24.1N	85.2W	24.1N	85.2W	24.1N	85.2W	24.1N	85.2W	24.1N	85.2W
18	24.4N	86.4W	24.3N	86.5W	24.4N	86.4W	24.3N	86.5W	24.3N	86.5W
24	24.5N	87.6W	24.4N	87.6W	24.4N	87.6W	244N	876W	244N	876W
30	24.7N	88.6W	24.7N	88.6W	24.7N	88.7W	24.7N	887W	248N	88.7W
36	25.2N	89.5W	25.2N	89.6W	25.2N	89.6W	25.1N	89.6W	251.N	89.7W
42	25.8N	90.6W	25.8N	90.6W	25.7N	90.7W	25.8N	90.7W	25.8N	90.8W
48	26.5N	91.6W	26.5N	91.6W	26.4N	91.6W	26.5N	91.7W	26.5N	91.8W
54	273N	92.6W	27.2N	92.6W	27.3N	92.7W	27.3N	92.8W	27.3N	92.8W
60	28.3N	93.3W	28.2N	93.4W	28.2N	93.5W	28.3N	93.6W	28.3N	93.6W
66	29.3N	94.2W	29.2N	94.2W	29.2N	94.4W	29.3N	94.4W	29.2N	94.5W
72	30.2N	94.6W	30.2N	94.6W	30.1N	94.7W	30.3N	94.8W	30.2N	94.9W
78	31.1N	94.8W	31.0N	94.8W	31.0N	95.1W	31.1N	95.1W	31.1N	95.2W
84	31.9N	94.8W	31.8N	94.9W	31.8N	95.1W	31.8N	95.1W	31.8N	95.3W
90	32.5N	94.7W	32.5N	94.7W	32.5N	95.0W	32.6N	95.0W	32.5N	95.2W
96	33.0N	94.5W	33.0N	94.6W	33.1N	94.7W	33.1N	94.7W	33.2N	94.7W
102	33.4N	94.1W	33.3N	94.1W	33.4N	94.4W	33.5N	94.3W	33.6N	94.4W
108	33.6N	93.6W	33.5N	93.6W	33.6N	93.8W	33.7N	93.7W	33.8N	93.8W
114	33.6N	93.1W	33.4N	93.3W	33.5N	93.4W	33.6N	93.3W	33.6N	93.3W
120	33.4N	92.7W	33.1N	93.0W	33.3N	930W	334N	92.8W	33.3N	92.7W
126	32.9N	92.9W	32.5N	93.2W	32.7N	93.3W	32.8N	93.0W	32.8N	92.8W

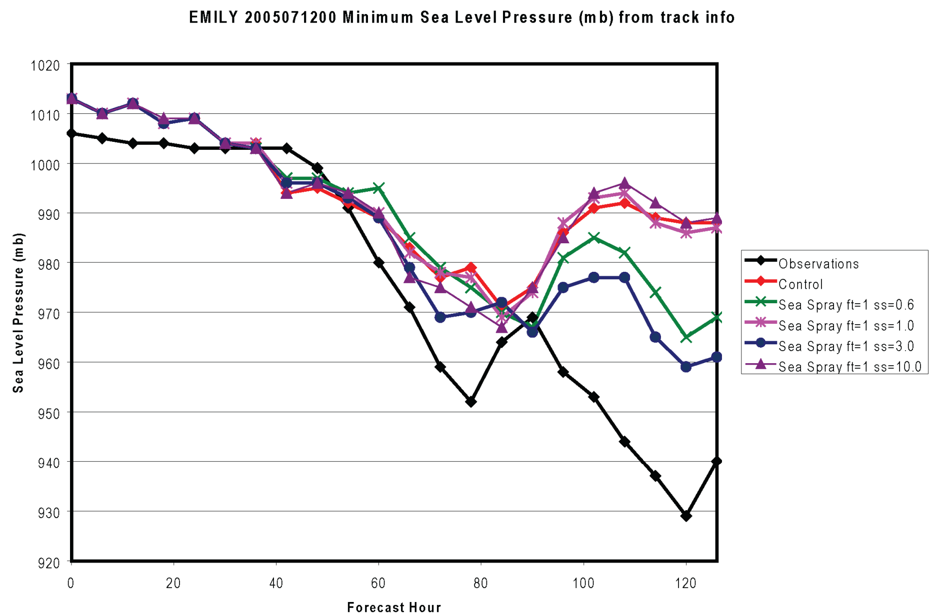
Table 2: Predicted track locations of Hurricane Rita without the sea-spray parameterization (control) and with the sea-spray parameterization in which *ss* = 0.6, 1, 3 and 10 while *ft* = 1.

4.3 Emily (2005)

The results from the sensitivity runs with Hurricane Emily (2005) are shown in Figure 3 and Table 3. The model was initialized at 0000 UTC 12 July 2005. While the predicted intensity is sensitive to *ss*, the predicted track does not show any significant sensitivity (Table 3). The nonlinear variation of the predicted intensity with *ss* is very similar to that shown in the Katrina and Rita case. However, there is delay in the predicted intensification and the second intensification shown in the best track estimate is significantly underestimated in the forecast. The inclusion of the sea spray effect does not help alleviate this problem.



(a)



(b)

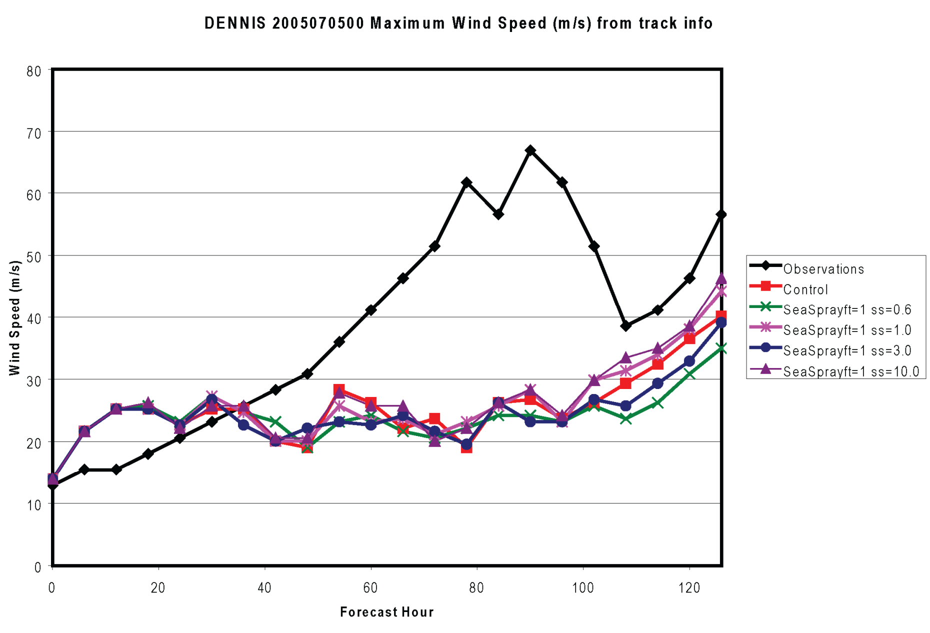
Figure 3: The maximum surface winds (ms^{-1}) (a) and sea-level pressure (mb) (b) for Hurricane Emily (2005) with *ss* = 0.6, 1, 3 and 10 while *ft* = 1. The black line (labeled as Observations) is the best track estimate. The red line is the control run without the sea-spray parameterization. The model was initialized at 0000 UTC 12 July 2005.

forecast hour	Control lat	Control lon	*ss*=0.6 lat	*ss*=0.6 lon	*ss*=1 lat	*ss*=1 lon	*ss*=3 lat	*ss*=3 lon	*ss*=10 lat	*ss*=10 lon
0	11.2N	46.3W	11.2N	46.3W	11.2N	46.3W	11.2N	46.3W	11.2N	46.3W
6	11.5N	47.7W	11.5N	47.8W	11.5N	47.7W	11.5N	47.7W	11.5N	47.7W
12	11.9N	49.3W	11.9N	49.3W	11.9N	49.3W	12.0N	49.3W	11.9N	49.3W
18	12.5N	51.1W	12.5N	51.0W	12.4N	51.1W	12.3N	51.2W	12.4N	51.2W
24	13.0N	52.5W	13.0N	52.5W	13.0N	52.5W	13.0N	5.26W	12.9N	52.5W
30	13.6N	54.1W	13.6N	54.0W	13.6N	54.0W	13.6N	54.0W	13.6N	54.0W
36	14.2N	55.7W	14.2N	55.8W	14.2N	55.8W	14.2N	55.8W	14.2N	55.8W
42	14.7N	57.5W	14.7N	57.7W	14.8N	575W	147N	57.6W	14.8N	57.6W
48	15.3N	59.1W	15.2N	59.3W	15.1N	59.2W	15.1N	59.2W	15.2N	59.1W
54	15.7N	61.0W	15.5N	61.0W	15.6N	61.0W	15.8N	60.9W	15.7N	60.9W
60	16.3N	62.5W	16.3N	62.4W	16.1N	62.5W	16.3N	62.5W	16.3N	62.6W
66	16.8N	64.1W	16.9N	64.1W	16.8N	64.1W	16.9N	64.1W	16.7N	64.0W
72	17.4N	65.4W	17.4N	65.4W	17.4N	65.4W	17.4N	65.4W	17.3N	65.4W
78	18.0N	66.9W	18.0N	66.9W	18.1N	67.0W	18.0N	66.8W	17.9N	66.9W
84	18.4N	68.2W	18.6N	68.1W	18.6N	68.3W	18.6N	68.0W	18.4N	68.2W
90	18.9N	69.4W	19.1N	69.3W	19.0N	69.6W	19.1N	69.1W	18.8N	69.4W
96	19.5N	70.5W	19.7N	70.4W	19.6N	70.7W	19.7N	70.3W	19.4N	70.6W
102	19.8N	71.9W	20.0N	71.8W	19.9N	72.0W	20.1N	71.6W	19.7N	71.9W
108	20.0N	72.9W	20.3N	72.8W	20.0N	73.1W	20.2N	72.8W	19.8N	72.9W
114	20.2N	74.0W	20.4N	74.0W	20.3N	740.W	20.3N	73.9W	20.2N	73.8W
120	20.8N	76.5W	20.6N	75.0W	20.6N	75.2W	20.4N	74.9W	20.5N	75.1W
126	20.8N	76.5W	20.9N	76.2W	21.0N	76.4W	20.8N	76.2W	20.7N	76.5W

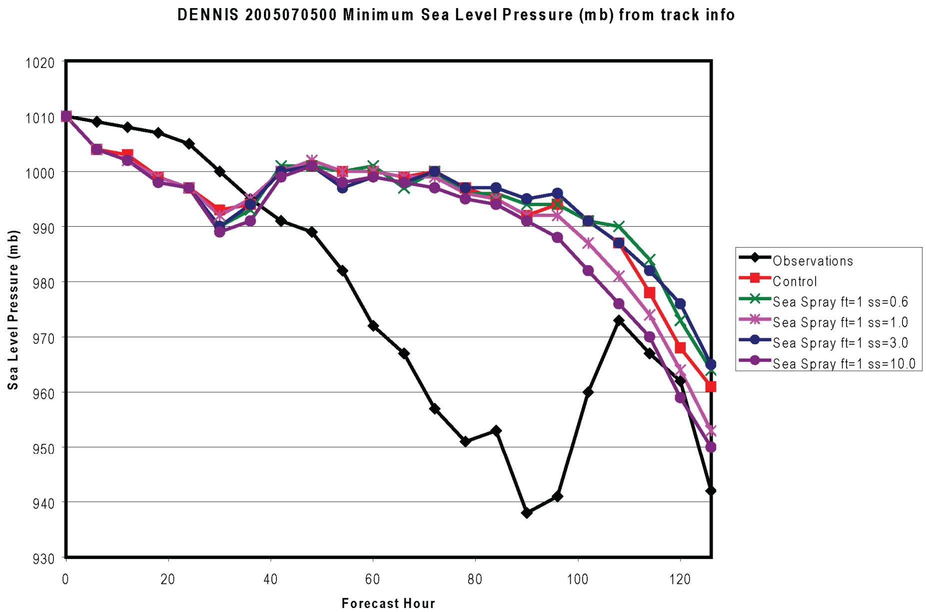
Table 3: Predicted track locations of Hurricane Emily without the sea-spray parameterization (control) and with the sea-spray parameterization in which *ss* = 0.6, 1, 3 and 10 while *ft* = 1

4.4 Dennis (2005)

Figure 4 and Table 4 show the results from the sensitivity runs with Hurricane Dennis (2005). The model was initialized at 0000 UTC 05 July 2005. Like in the previous cases, while the predicted intensity is sensitive to *ss*, the predicted track does not show significant sensitivity. The variation of the predicted intensity with *ss* is very nonlinear. It is interesting to note that predicted storm does not intensify in any of the runs**.** This is due to the fact that all the predicted tracks are much farther northward than the best track estimate such that they all pass over the Caribbean Islands when the real storm was still over the open water and intensifying. Again, the inclusion of sea-spray effect is not capable of correcting the track prediction. Additionally, the intensity of Hurricane Dennis is not as sensitive to *ss* as seen in the previous cases. This can be attributed to the fact that the predicted track from all the runs has such great errors that the predicted storm does not intensify and the maximum wind speeds do not reach 30 ms^{-1} until after 100 hours into the forecast. The sea-spray parameterization scheme has little effect on intensity until wind speeds are greater than 30 ms^{-1}, which is consistent with the observational finding that the impact of sea spray on air-sea thermal fluxes is insignificant for wind speed less than 30 ms^{-1}.



(a)



(b)

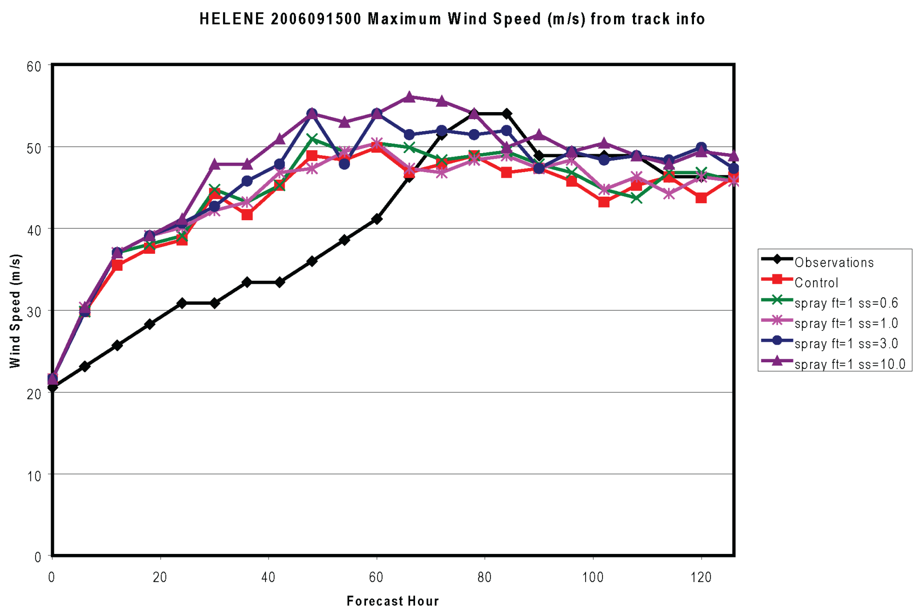
Figure 4: The maximum surface winds (ms^{-1}) (a) and sea-level pressure (mb) (b) for Hurricane Dennis (2005) with *ss* = 0.6, 1, 3 and 10 while *ft* = 1. The black line (labeled as Observations) is the best track estimate. The red line is the control run without the sea-spray parameterization. The model was initialized at 0000 UTC 05 July 2005.

forecast hour	Control lat	Control lon	*ss*=0.6 lat	*ss*=0.6 lon	*ss*=1 lat	*ss*=1 lon	*ss*=3 lat	*ss*=3 lon	*ss*=10 lat	*ss*=10 lon
0	12.2N	62.3W	12.2N	62.3W	12.2N	62.3W	12.2N	62.3W	12.2N	62.3W
6	12.7N	63.6W	12.7N	63.7W	12.8N	63.7W	12.8.N	63.7W	12.8N	63.7W
12	13.9N	65.2W	13.9N	65.3W	13.9N	65.2W	13.9N	65.3W	13.9N	65.3W
18	15.2N	66.9W	15.2N	66.9W	15.2N	66.9W	15.2N	66.9W	15.2N	66.9W
24	16.5N	68.3W	16.5N	68.3W	16.5N	68.4W	16.5N	68.3W	16.5N	68.3W
30	17.3N	69.8W	17.3N	69.8W	17.3N	69.8W	17.3N	69.7W	17.2N	69.9W
36	18.3N	71.2W	18.3N	71.3W	18.2N	71.4W	18.3N	71.3W	18.3N	71.4W
42	19.1N	72.7W	19.2N	72.6W	19.1N	72.5W	19.1N	72.8W	19.0N	72.6W
48	19.6N	73.5W	19.8N	73.6W	19.7N	73.5W	19.4N	73.5W	19.8N	73.5W
54	20.3N	74.2W	20.2N	74.5W	20.3N	74.2W	20.4N	74.3W	20.1N	74.4W
60	21.4N	75.0W	21.5N	75.0W	21.5N	75.1W	21.3N	75.1W	21.3N	75.3W
66	22.6N	75.9W	22.7N	76.2W	22.4N	76.0W	22.7N	76.0W	22.4N	76.2W
72	23.5N	77.0W	23.1N	77.1W	23.3N	77.0W	23.5N	77.3W	23.2N	77.4W
78	23.9N	78.2W	23.4N	78.1W	23.9N	77.9W	23.6N	78.1W	23.4N	78.1W
84	24.1N	78.6W	24.5N	78.4W	24.4N	78.5W	24.7N	78.3W	24.5N	78.5W
90	25.1N	78.7W	25.4N	78.8W	25.4N	78.8W	25.5N	78.8W	25.4N	78.7W
96	26.3N	78.7W	264.N	78.9W	26.5N	78.9W	26.7N	78.9W	26.9N	79.2W
102	27.5N	78.9W	27.5N	78.7W	27.5N	79.0W	27.6N	79.0W	27.7N	79.3W
108	28.9N	78.8W	29.3N	78.7W	28.9N	78.7W	29.2N	78.7W	29..4N	78.9W
114	30.4N	78.6W	30.9N	78.5W	30.4N	78.6W	30.9N	78.4W	31.1N	78.7W
120	31.9N	77.8W	32.4N	77.7W	32.0N	77.7W	32.5N	77.9W	32.9N	78.0W
126	33.4N	76.6W	34.0N	76.5W	33.5N	76.8W	34.3N	76.8W	34.6N	77.0W

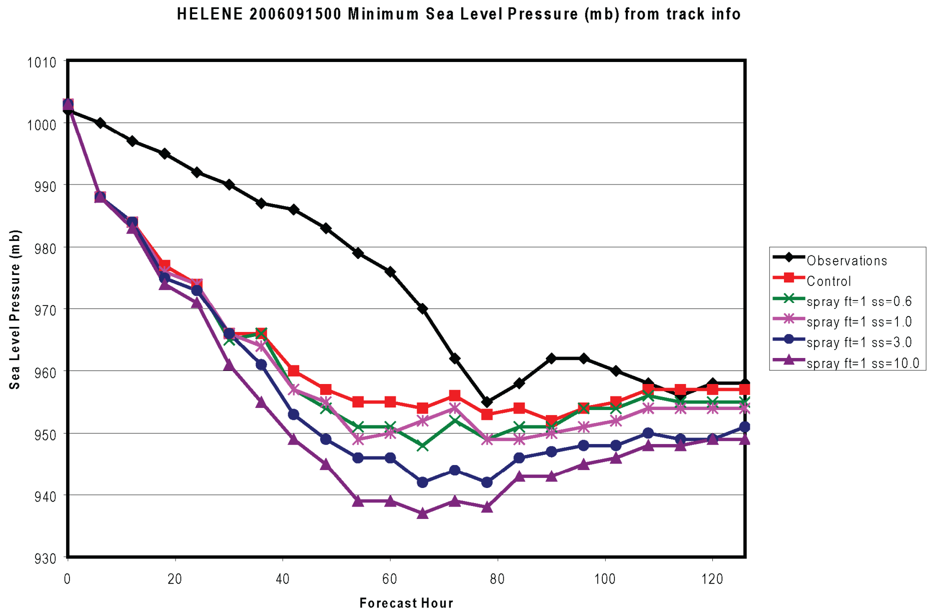
Table 4: Predicted track locations of Hurricane Dennis without the sea-spray parameterization (control) and with the sea-spray parameterization in which *ss* = 0.6, 1, 3 and 10 while *ft* = 1.

4.5 Helene (2006)

The results from the sensitivity runs with Hurricane Helene (2006) (initialized at 0000 UTC 15 September 2006) are different from the previous cases. In this case, the predicted intensity in the control run is greater than the best track estimate. When the sea-spray effect is included, the predicted storm deepens even more than that from the control run, further worsening the over-prediction of the intensity. However, as in the previous cases, while the predicted intensity is sensitive to *ss*, the predicted track does not show significant sensitivity and the variation of the predicted intensity with *ss* is similarly nonlinear. On the other hand, unlike the previous cases, the predicted intensification takes place earlier and faster than the best track estimate shows. This is, perhaps, related to the fact that the predicted track in all the runs are so much different than the best track estimate (see Table 5) that the predicted storm is under the influence of different background winds and the underneath sea-surface temperatures than the real storm. Further study is required to pin down the real causes for the discrepancy between the forecast and the best track estimate.



(a)



(b)

Figure 5: The maximum surface winds (ms^{-1}) (a) and sea-level pressure (mb) (b) for Hurricane Helene (2006) with *ss* = 0.6, 1, 3 and 10 while *ft* = 1. The black line (labeled as Observations) is the best track estimate. The red line is the control run without the sea-spray parameterization. The model was initialized at 0000 UTC 15 September 2006.

forecast hour	Control lat	Control lon	*ss*=0.6 lat	*ss*=0.6 lon	*ss*=1 lat	*ss*=1 lon	*ss*=3 lat	*ss*=3 lon	*ss*=10 lat	*ss*=10 lon
0	14.2N	38.3W	14.2N	38.3W	14.2N	38.3W	14.2N	38.3W	14.2N	38.3W
6	14.9N	39.5W	14.9N	39.5W	14.9N	39.5W	14.9N	39.5W	14.9N	39.5W
12	15.8N	40.7W	15.8N	40.7W	15.8N	40.7W	15.8N	40.7W	15.8N	40.7W
18	16.6N	41.7W	16.6N	41.7W	16.7N	41.7W	16.6N	41.7W	16.6N	41.7W
24	17.3N	42.5W	17.3N	42.5W	17.3N	42.6W	17.3N	42.5W	17.3N	42.5W
30	18.0N	43.7W	18.0N	43.7W	18.0N	43.6W	18.0N	43.5W	18.0N	43.6W
36	18.5N	44.2W	18.5N	44.3W	18.4N	44.0W	18.5N	44.1W	18.5N	44.4W
42	19.1N	44.8W	19.1N	45.0W	19.0N	44.8W	19.1N	44.8W	19.1N	45.0W
48	19.5N	45.5W	19.5N	45.6W	19.5N	45.4W	19.5N	45.4W	19.5N	45.5W
54	19.9N	46.0W	19.9N	46.1W	19.8N	45.9W	19.9N	45.8W	19.9N	46.1W
60	20.2N	46.3W	20.2N	46.6W	20.2N	46.2W	20.3N	46.3W	20.3N	46.5W
66	20.6N	46.6W	20.6N	47.0W	20.6N	46.6W	20.7N	46.8W	20.7N	46.9W
72	21.2N	46.9W	21.1N	47.3W	21.2N	46.9W	21.2N	47.0W	21.4N	47.1W
78	21.8N	47.3W	21.8N	47.6W	21.7N	47.2W	21.9N	47.3W	22.0N	47.6W
84	22.5N	47.7W	22.5N	48.0W	22.5N	47.5W	22.6N	47.7W	22.7N	48.0W
90	23.2N	48.0W	23.2N	48.4W	23.2N	48.1W	23.4N	48.1W	23.4N	48.5W
96	24.0N	48.4W	23.9N	48.7W	24.0N	48.3W	24.1N	48.4W	24.2N	48.8W
102	24.7N	48.8W	24.7N	49.1W	24.8N	48.8W	24.9N	48.9W	24.9N	49.2W
108	25.5N	49.3W	25.4N	49.6W	25.5N	49.2W	25.7N	49.4W	25.7N	49.7W
114	26.3N	49.7W	26.2N	49.9W	26.3N	49.7W	26.6N	49.8W	26.6N	50.0W
120	27.2N	50.3W	27.1N	50.4W	27.1N	50.2W	27.5N	50.3W	27.6N	50.5W
126	28.3N	50.8W	28.2N	50.9W	28.1N	50.8W	28.6N	50.8W	28.7N	51.0W

Table 5: Predicted track locations of Hurricane Helene without the sea-spray parameterization (control) and with the sea-spray parameterization in which ss = 0.6, 1, 3 and 10 while ft = 1.

5. SUMMARY AND CONCLUSIONS

This report presents the results from the first six months of our Joint Hurricane Testbed project in which a bulk parameterization scheme of air-sea sensible and latent heat fluxes developed at NOAA/ESRL is implemented and tested in the HWRF model. Preliminary test of the scheme with the current operational setup of the HWRF model indicates that the scheme performs as well as expected. The major findings from all the sensitivity runs so far are:

1. The NOAA/ESRL sea-spray parameterization scheme is an effective physics option to alleviate the underestimate bias in the HWRF predicted intensity.

2. The impact of the inclusion of the sea-spray effect on the hurricane track prediction is so small that it can be neglected.

3. There is significant sensitivity in the HWRF predicted intensity to the uncertainties of two parameters, droplet source strength and feedback strength**,** in the sea-spray parameterization scheme.

4. Due to the nonlinear interaction between the air-sea thermal fluxes and dynamical processes associated with the hurricane intensification, the response of the predicted storm intensity is noticeably nonlinear to the change of droplet source strength and feedback strength.

5. The fact that the inclusion of the sea-spray only increases the intensification upon the control run strongly suggests that errors in the HWRF model forecast can only be partially attribute to the errors in the thermal fluxes across the air-sea interface. The errors in other controlling factors in the intensification forecast such as the background wind shear and the eye-wall contraction dynamics are as significant as those in the air-sea fluxes.

6. REFERENCES

Fairall, C. W., W. Asher, M. Banner, and W. Peirson, 2007: Investigation of the physical scaling of sea spray spume droplet production. *J. Geophys., Res.*, in preparation.

Fairall, C.W., J.D. Kepert and G.J. Holland, 1994: The effect of sea spray on surface energy transports over the ocean. *The Global Atmosphere and Ocean System*, **2**,121-142.